

Design of a compact micro-strip patch antenna with enhanced bandwidth on modified ground plane for x-band applications

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Abstract. Introduction: A compact MPA has been presented with an increased bandwidth for X band applications. A 24 mmX15.6mmX1.6mm is designed and fabricated on FR4 substrate with co-axial probe fed excitation. **Methodology:** Here Commercially available integrated electromagnetics 3dimensional (IE3D) is used for simulation. Bandwidth is increased in the desired band by changing the shape of the patch to Ψ and also by placing an inverted L slot on ground plane which generates two adjacent resonances. **Results:** The antenna is resonating at 10.53 GHz & 11.71GHz giving a return loss of -28.49dB and -25.74dB. In the desired X-band (8GHz-12GHz) the antenna is giving an impedance bandwidth of 3.99GHz from 8.28GHz – 12.27GHz which is below -10dBi. A maximum peak gain of 7.51 dB is attained at the operating frequency with a good radiation pattern and less cross polarization. The parametric study of the proposed patch antenna is done w.r.t slots, height of the substrate and substrate material. The proposed antenna is fabricated and tested the results using VNA shows in good agreement between simulated and measured. The proposed antenna compared with the existing ones w.r.t results.

Keywords: Coaxial probe, FR4 substrate material, Inverted L slot, MPA, X-band.

1 Introduction

Due to the changes in wireless communication systems, demands for new generation of antenna technology. MPA is one which will fulfill the demands of Wireless communication due to its attractive advantages like less profile, low weight, low cost, easy to fabricate and conformal design. MPA has a dielectric substrate with one side patch and on other side ground plane [1-2]. Apart from advantages it has limitations as lower power handling, lower bandwidth low efficiency. To overcome these limitations many techniques has been proposed in literature. Many researches have proposed different techniques to enhance the bandwidth like stacked multi resonator, multi layered, modifying the shape of the patch, modifying the ground plane etc.[3-5].

Among these modifying the shape of the patch and ground plane (by placing slots) are the easier methods with respect to design and size [6-8]. Due to high data transmission rates, short range and large bandwidth X band technology is widely used. A circular and rectangular slot antenna for X-band applications is proposed but this gives a bandwidth of 1.5 GHz and of 40x40mm in size [9]. On modified ground planes a U shaped patch antenna is proposed with a size of 36 x36mm and a maximum gain of 4.1dB [10]. A slot on swasthik patch antenna is proposed on 30 x 30 is proposed for X band applications [11]. With a wide bandwidth of size 70

X70mm is proposed which is too large [12]. An E-slot patch antenna with micro-strip line feed and CPW feed is designed with enhanced BW but dimension is 85x85mm is too large [13].

In this paper by placing an inverted L slot on ground plane and by changing the shape as ψ makes the patch to resonate at nearby frequencies to improve the bandwidth to 3.99GHz an improvement of 82.4% in X-band, with a size reduction of 41.6% [11] and a gain of 60%. Parametric study is done with respect to height and dielectric substrate and is discussed in detail.

2. Antenna Geometry and Design

In order to increase the bandwidth, the shape of the patch is changed to Ψ and also placed an inverted L shaped slots on the ground plane. Fig 1 shows the proposed MPA and a modified ground plane. The design procedure starts with the selection of parameters like Resonating frequency, Dielectric constant of the substrate, height of the substrate, type of feed and size of the ground plane. The patch antenna is tested on a 1.6 mm thick Flame Resistant (FR4) substrate that has relative permeability 1, relative permittivity 4.50, and dielectric loss tangent of 0.025. The proposed antenna is fed with coaxial probe. The SMA connector with 50Ω impedance is connected at (12, 3.925) as a feeding line to give RF signal as input.

The transmission line model (TEM) approximations used to design micro-strip patch antenna. Using the following below equations the width and length of the MPA can be designed for the given f_0 .

$$W = \frac{c}{2f} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$\lambda_g = \frac{c}{f\sqrt{\epsilon_{\text{reff}}}}, \quad L = \frac{\lambda_g}{2} - 2\Delta L \quad (2)$$

Where, W is the width of the radiating patch, L is the length of the radiating patch and λ_g is the guided wavelength f_0 is the desired resonance, c is used to indicate the light speed in a vacuum. ϵ_{reff} is the effective dielectric constant is determined using the following equation:

$$\epsilon_{\text{reff}} = \left(\frac{\epsilon_r + 1}{2}\right) + \left(\frac{\epsilon_r - 1}{2}\right) \left(1 + 12 \frac{h}{w}\right)^{-1/2} \quad (3)$$

Where, ϵ_r is the substrate dielectric constant and the substrate thickness is indicated as h . Due to the fringing fields around the periphery of the patch, the antenna looks larger than its physical dimensions ΔL accounts for this which is given by the following equation

$$\Delta L = 0.412 h \left[\frac{(\epsilon_{\text{reff}} + 0.3) \left(\frac{w}{h} + 0.264\right)}{(\epsilon_{\text{reff}} - 0.258) \left(\frac{w}{h} + 0.8\right)} \right] \quad (4)$$

The input impedance of the micro-strip patch antenna is calculated and must be made equal to the probe impedance of 50Ω. We can calculate the correct co-ordinate of the feeding point using the following equations.

$$G1 = \frac{1}{120} \left(\frac{w}{\lambda_0}\right) \quad (5)$$

$$Y_{\text{in}} = 2 G1, Z_{\text{in}} = \frac{1}{Y_{\text{in}}} \quad (6)$$

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$$R_{in} = \frac{1}{2G_1} [\cos^2(\frac{\pi}{L}y_0)] \tag{7}$$

Where Y_0 is the feed point and $R_{in} = 50\Omega$.

Keeping dielectric constant and bandwidth as objectives the antenna is first designed to operate in X band by using above equations then optimized to achieve optimum size and bandwidth of the radiating patch. Finally the satisfactory dimensions have been tabulated in table 1. The geometry of the proposed antenna from simulation software and fabricated one is shown in figure 2.

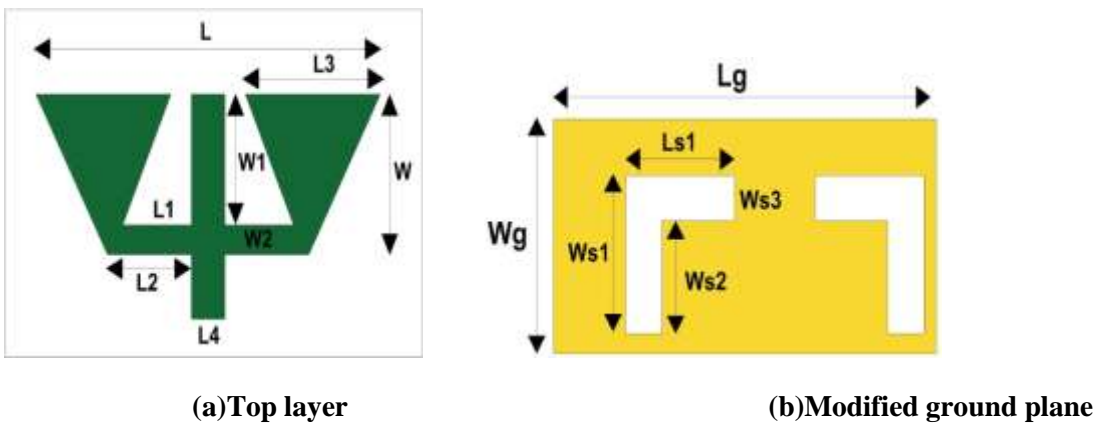


Figure.1. Geometries of the proposed patch antenna

Table 1. Proposed Antenna Specifications (All units are in mm)

Parameter	W	L	W1	W2	L1	L2	L3	Wg	Lg	Ls1	Ls2	Ws1	Ws2	Ws3
Proposed Antenna	15.6	11.6	11.4	0.6	1.43	3.5	5.3	3.2	24	2.4	1.2	2.4	1.8	0.6



Figure 2. Fabricated geometry of the proposed antenna

3. Results and Discussion

In order to get the required performance the patch is simulated using Integrated Electromagnetic 3 dimension (IE3D). Return loss indicates the amount of power reflected back, for MPA's the acceptable value of S11 must be less than -10dB. The patch is resonating at two frequencies to increase the bandwidth. The patch is resonating at 10.38 GHz and 11.71 GHz giving a return loss of -28.49dB and -25.74 dB respectively which is shown in figure 3. In X band we got 3.99 GHz (8.28GHz – 12.27GHz) bandwidth. The patch is fabricated and tested through Vector network analyzer (VNA) and the results shows that apart from X band the patch are resonating in C band from 5.61 GHz to 6.58GHz due to feed radius variation and fabrication errors.

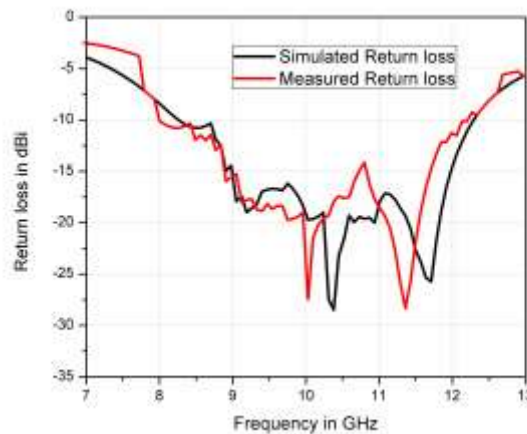


Figure 3: Return Loss of the proposed antenna simulated and measured

3.1. Parametric Evaluation:

To investigate the effect of parameters on antenna performance, some parameters are identified and studied based on design. Parametric study have been performed with respect to (a) Presence of inverted L slot on ground plane (b) Effect of thickness of the substrate (c) Effect of dielectric constant of the material. All simulation has been carried out by using IE3D simulator.

3.1.1 Presence of an inverted L slot on ground plane:

To study the effect of an inverted L slot on ground plane on antenna performance, keeping all other parameters fixed a simulation is carried out without an inverted L slot is presented in Fig 4. It can be observed that an inverted L slot has a significant effect on the bandwidth. The Ψ patch without an inverted u slot on ground plane resonates at 10.44 GHz and 11.56 GHz. In X band we got 2.08 GHz (10.15GHz – 12.23GHz) bandwidth. The same antenna with an inverted L slot on ground plane is resonating at 10.38 GHz and 11.71 GHz; we got an impedance bandwidth of 3.99 GHz (8.28GHz – 12.27GHz). On comparing the effect of slots, without slots patch is giving a small bandwidth. With slots at proper positions resonates at nearby multiple frequencies which increases the bandwidth.

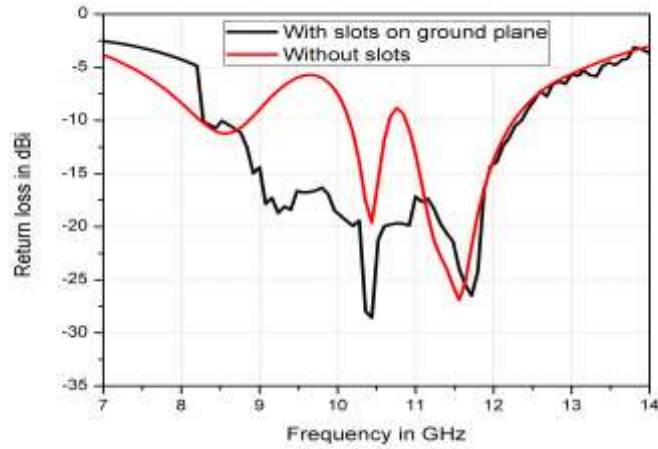


Figure 4: Return Loss of the proposed Antenna with and without slots on ground plane

3.1.2. Variation of height of the substrate:

Considering the same structure, by decreasing the height of the substrate the antenna 1 is giving S11 less than -10dB from 11.9 GHz to 16.1 GHz giving a bandwidth of 4.2GHz which is shown in figure 5. Considering the same structure again, by increasing the height of the substrate the antenna 2 is giving S11 less than -10dB from 8.11 GHz to 10.15 GHz giving a bandwidth of 2.04 GHz. This shows that the resonating frequency is inversely proportional to the height of patch.

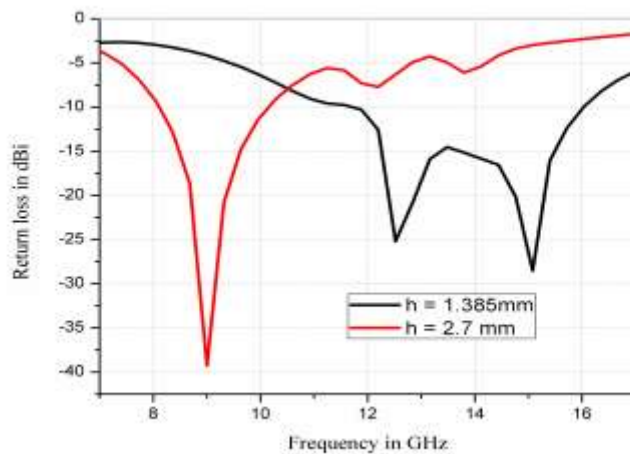


Figure 5: Return Loss of the proposed Antennas with respect to the variation of height

3.1.3. Variation of dielectric constant of the substrate material:

Considering the same structure, by changing the material of substrate i.e choosing RT Duriod with dielectric constant as 2.22 and loss tangent of 0.0009 and a height of 2.72mm the antenna 3 is giving S11 less than -10dB from 8.49GHz to 10.49GHz giving a bandwidth of 2 GHz which is shown in figure 6.

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Considering the same structure again, by choosing LCP substrate with a dielectric constant of 3.1 and loss tangent of 0.002 and height of 1.385 antennas 4 is designed and is giving S11 less than -10dB from 11.06GHz to 14.76GHz giving a bandwidth of 3.16GHz which is shown in figure 6. This shows that this patch antenna is sensitive variation of dielectric substrate material.

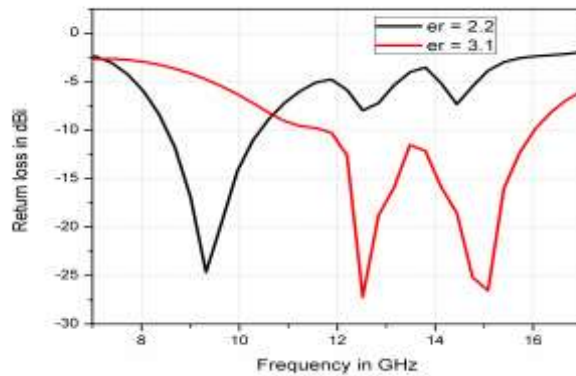


Figure 6: Return Loss of the proposed Antennas with respect to the variation of dielectric substrate.

Voltage standing wave ratio must be between 1 & 2 indicates a minimum reflection. Antenna 1 is giving a minimum VSWR of 1.03 at 9.98 GHz frequency and Antenna 3 is giving a minimum of 1.12 at 9.42GHz frequency. The proposed antenna and antenna 1 is giving a maximum gain of 7.54 dB and 3.12dB at their resonating frequencies.

Table2: Comparison Results of the Proposed Antennas with respect to height and ϵ_r .

Antennas	Bandwidth in GHz	Dielectric Constant (ϵ_r)	Size in mm	Maximum Gain in dB	Resonating Frequency f_0 in GHz
Pro.Ant	3.99	4.5	24 X 15.6X 1.6	7.51@11.76 GHz	10.38 & 11.71
Ant1	4.2	4.5	24 X 15.6X 1.385	5.56 @14.95GHz	12.56 &14.95
Ant2	2.04	4.5	24 X 15.6X 2.7	3.12 @ 9.01 GHz	9.01
Ant3	1.91	2.22	24 X 15.6X 2.7	4.24 @ 9.28GHz	9.28
Ant4	3.16	3.1	24 X 15.6X 1.385	4.15@13.81 GHz	13.16 &13.81

When excitation is applied to a radiating patch antenna the current distribution over the surface is shown in figure 7. Current distribution indicates the mode generation and is given by an arrow sign. The Co and cross Polarization components of one of the proposed antenna 1 in E-plane is shown in figure 8. Cross polarization must be less than -20dB for practical antennas, from figure it is shown that cross polarization is -49.58dB.

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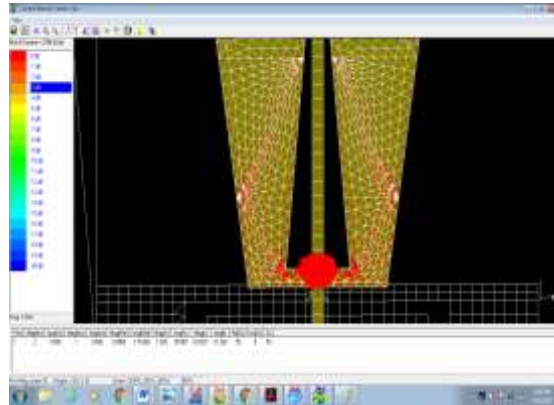


Figure.7 Current Distribution of the proposed antenna

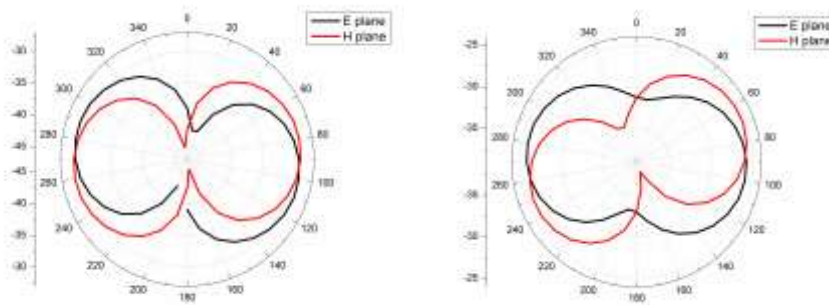


Figure .8 co-polar radiation patterns of proposed ψ -shape patch in E & H planes at 9.32GHz and 13.7GHz

Table 3. Work Comparison

Parameters	[9]	[10]	[11]	[12]	Our Work
Resonating Frequency in GHz	10.25 &11.54	7.9 , 5.5 &10.5	9.5	8.95, 11.06, 11.85	10.53 &11.76
Bandwidth in GHz	1.59	6	1.56	0.45, 1.01	3.99
Radiating Patch Size including ground plane in mm	40 x40 x 1.6	36 x 36 x 1.6	30 x 30 x1.6	20 x 17.2 x 1.6	24 X 15.6X 1.6
Return Loss at resonating frequencies in dB	-17.14 &-14.29	-15 ,-25 & -18	-24	-24	-28.49 & -25.74
Peak Gain in dB	4.31	4.1	4.5	4.45, 3.99, 4.17	7.51

4. Conclusion

For X- band applications a compact micro-strip patch antenna with Enhanced bandwidth is presented here. As the antenna layout is simple, Fabrication is easier. The patch is resonating at two adjacent frequencies which increased the bandwidth. The antenna is resonating at 10.53 GHz & 11.76GHz giving a return loss of -28.49dB and -25.74dB, with a bandwidth and maximum gain of 3.99GHz & 7.51dB respectively. Antenna is fabricated and tested through VNA and there is a good agreement of results between simulated and measured. Parametric study of the proposed antenna is also done with respect to slots, height and substrate material and the results are tabulated. Comparison study reveals that the attractive results of low cross polarization, good radiation patterns with high gain , improved bandwidth and compact in size proves that the proposed antenna can be used for X band applications.

References

- [1] Kumar, G. and Ray, K.P., Broadband Microstrip Antennas, Artech House, Boston, 2003.
- [2] Ramesh Garg, Prakash Bartia, Inder Bahl, Apisak Ittipiboon, ‘Microstrip Antenna Design Handbook’, 2001.
- [3] J.-Y. Sze, and K. -L. Wong, “Bandwidth enhancement of a micro strip line-fed printed wide-slot antenna,” IEEE Trans. Antennas Propag. vol. 49, no. 7, pp. 1020-1024, 2001.
- [4] J.-Y. Jan and J.-W. Su, “Bandwidth enhancement of a printed wide-slot antenna with a rotated slot,” IEEE Trans. Antennas Propag. vol. 53, no. 6, pp. 2111-2114, 2005.
- [5] J.X.Xiao, M.F.Wang, and G.J.Li, “A ring monopole antenna for UWB application,” Microw. Opt. Technol. Lett., vol. 52, no. 1, pp. 179-182, 2010.
- [6] Anitha P, A.S R Reddy , M.N Giri Prasad “Performance Analysis of Compact CPW-Fed Modified ψ -Shaped Micro-strip Antenna for Dual Band” International Conference on Communication and Signal Processing, IEEE, April 6-8, 2016, India
- [7] Anitha P, A.S R Reddy , M.N Giri Prasad “Performance comparison of Modified ψ -Shaped Micro-strip Antenna with compact shorted ψ -Shaped patch” Proceedings of ICMARS, Dec 15-17, 2015, Jodhpur, India
- [8] Anitha P, A.S R Reddy , M.N Giri Prasad “Design of a Compact ψ -shaped Micro-strip Patch antenna on Modified Ground Planes” ICRAECT, IEEE, Mar 23-25, 2017, India
- [9] M. M. Islam, M. T. Islam, M. R. I. Faruque, W. Hueyshin “Design of an X-band microstrip patch antenna with Enhanced bandwidth” 2nd International Conference on Advances in Electrical Engineering (ICAEE 2013) IEEE, 19-21 December, 2013, Dhaka, Bangladesh.
- [10] Kaushik Mandal and Partha Prtim Sarkar “High Gain Wide-Band U-Shaped Patch Antennas With Modified Ground Planes” IEEE Trans. Antennas Propag., vol. 61, no. 4, pp. 2279-2282, Apr-2013.
- [11] Vivek Singh, Brijesh Mishra, Rajeev Singh “ A Compact and Wide Band Microstrip Patch Antenna for X-Band Applications” Advances in Computing and Communication Engineering (ICACCE), 2015 Second International Conference on, IEEE, 1-5 May 2015L.

- [12] M. Samsuzzaman and M. T. Islam “ Inverted S-Shaped Compact Antenna for X-Band Applications” Hindawi Publishing Corporation the Scientific World Journal Volume 2014, Article ID 604375.
- [13] A. Dastranj and H. Abiri, “Bandwidth enhancement of printed E-shaped slot antennas fed by CPW and Microstrip line,” IEEE Trans. Antennas Propag., vol. 58, no. 4, pp. 1402-1407, 2010.
- [14] Anitha P, A.S R Reddy , M.N Giri Prasad “ Design of a Compact Dual Band Patch Antenna with Enhanced Bandwidth on Modified Ground Plane” IJAER, Vol.13, no. 1, pp. 118-122, Jan-2018.